DECLARATION

I, Keiko Kondo, c/o YAMADA PATENT OFFICE of The Tanabe Bldg., 6-6, Fushimimachi 2-chome, Chuo-ku, Osaka-shi, Osaka, Japan, declare that I am the translator of the documents attached, which are to the best of my knowledge and belief a true and correct translation of International Application No. **PCT/JP2004/011330**.

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Signature of translator Keiko Kondo

Keiko Kondo

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SPECIFICATION

Patch Antenna

TECHNICAL FIELD

The present invention relates to a patch antenna. More specifically, the present invention relates to a patch antenna that has a ground conductor and a patch conductor formed on respective main surfaces of a dielectric substrate and possesses asymmetric directivity, which is used for cellular telephones.

PRIOR ART

In a cellular telephone, since it is used close to the head of a person, there is a decrease in antenna gain under the influence of the head. Thus, in order to reduce the influence of coupling with the human body, it is contemplated to make directivity asymmetrical between the direction of the human body (head) and the other directions.

One example of patch antenna with asymmetrical directivity is disclosed in Japanese Patent Laying-open No. 8-186437 [H01Q 21/28, G01S 7/03, H01Q 13/08, 21/06] (patent document 1) and Japanese Patent Laying-open No. 10-270932 [H01Q 13/08, 19/10] (patent document 2).

The prior art of patent document 1 is provided with a high-frequency phased-array antenna on a low-frequency patch antenna. By achieving wide-range directivity with the low-frequency patch antenna and achieving directivity for a predetermined direction with the high-frequency phased-array antenna, it is possible to design or set arbitrary directivity.

The prior art of patent document 2 is provided with a passive element mounted at a position with a specific spacing from a patch antenna element, two of which are the same

in shape and size. The passive element plays a role as reflector and reflects an antenna pattern in an arbitrary direction to obtain asymmetrical directivity.

In the prior art of patent document 1, not only its structure becomes complicated but also its size is too large to be used at relatively low frequencies on which cellular telephones operate, for example. Also, in the prior art of patent document 2, it is necessary to leave a distance of about 1/2 wavelength between the two patches, and if calculated with a frequency for cellular telephone, 2GHz, for example, the distance is as long as about 7.5cm. Therefore, as with the prior art of patent document 1, it is difficult to apply this prior art to small devices such as cellular telephones due to the limited built-in place.

SUMMARY OF THE INVENTION

Therefore, it is a primary object of the present invention to provide a novel patch antenna.

It is another object of the present invention to provide a patch antenna that has asymmetrical directivity and also can be reduced in size.

The present invention is a patch antenna including a dielectric substrate, a ground conductor formed on one main surface of the dielectric substrate, and a patch conductor formed on the other main surface of the dielectric substrate, wherein radiation efficiency is changed in a direction of wavelength-dependent length of the patch conductor.

By changing the radiation efficiency in the direction of wavelength-dependent length of the patch conductor, an antenna directional characteristic in that direction is altered, which makes it possible to achieve asymmetrical directivity.

According to the present invention, the asymmetrical directivity can be achieved just by changing the radiation efficiency, which allows downsizing without having to use

any phased-array antenna or reflecting passive element of prior arts.

In one embodiment, for changing the radiation efficiency, a spacing between the patch conductor and the ground conductor is made nonuniform in the direction of wavelength-dependent length.

Additionally, in another embodiment, for making nonuniform the spacing between the patch conductor and the ground conductor, thickness of the dielectric substrate is changed in the direction of wavelength-dependent length of the dielectric substrate.

Moreover, in still another embodiment, for changing the radiation efficiency, a dielectric constant is changed in the direction of wavelength-dependent length.

Besides, by loading a dielectric on the patch conductor, it is possible to decrease the length of the patch conductor of the antenna in the direction of wavelength-dependent length and thus obtain the compact patch antenna in its entirety.

In making it built into a cellular telephone, this patch antenna is arranged in such a manner that the length of the above mentioned patch conductor in the direction of wavelength-dependent length is in parallel with the direction of thickness of the housing of the cellular telephone, and that a side with higher radiation efficiency is faced opposite to a side making contact with the head of a person. By doing this, it is possible to effectively lessen a decrease in antenna gain resulting from coupling with the person's head.

The above described objects and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view showing a patch antenna of one embodiment of the present invention;

Figure 2 is a side view of the patch antenna of Figure 1 embodiment;

Figure 3 is a graph showing changes in radiation efficiency measured at an experiment with Figure 1 embodiment;

Figure 4 is an illustrative view showing changes in antenna gain calculated with Figure 1 embodiment;

Figure 5 is an illustrative view showing an E-plane radiation pattern obtained with Figure 1 embodiment;

Figure 6 is an illustrative view showing an E-plane radiation pattern of a conventional patch antenna;

Figure 7 is an illustrative view showing a modified example of Figure 1 embodiment;

Figure 8 is an illustrative view showing another modified example of Figure 1 embodiment;

Figure 9 is an illustrative view showing still another modified example of Figure 1 embodiment;

Figure 10 is an illustrative view showing another embodiment of the present invention;

Figure 11 is a perspective view showing a patch antenna of still another embodiment of the present invention;

Figure 12 is a side view of the patch antenna of Figure 11 embodiment;

Figure 13 is a perspective view showing a patch antenna of yet another embodiment of the present invention;

Figure 14 is a side view of the patch antenna of Figure 13 embodiment; and

Figure 15 is an illustrative view showing one example of portable information terminal with the patch antenna of the present invention built-in.

BEST MODE FOR PRACTICING THE INVENTION

A patch antenna 10 of the embodiment shown in Figure 1 and Figure 2 includes a substrate 12 formed of a dielectric. In this embodiment, the dielectric substrate 12 is alumina, and its dielectric constant (εr) is 9.7, for example. However, other ceramic dielectrics may be used for the dielectric substrate 12, and also any dielectrics other than ceramic dielectrics may be employed. The dimensions of the patch antenna 10 are about 50mm wide x 60mm long x 4mm thick in its entirety. However, this size is just one example and may vary depending on the dielectric constant and the frequency.

A patch conductor 14 having a width of 10mm and made of a metal such as copper is formed on an upper main surface of the dielectric substrate 12 at a center in a width direction of the substrate. Also, a length of the patch conductor 14 is determined by a wavelength (frequency) used with this antenna. Since the patch antenna 10 of this embodiment is to be used for cellular telephones with a frequency band of 2GHz, the patch conductor 14 is assumed to be 25mm long. Such length depending on the wavelength may be called wavelength-dependent length.

In addition, a step 16 is formed on a lower main surface of the dielectric substrate 12, as can be seen well from Figure 2, in particular. In this embodiment, assuming that the length of the dielectric substrate 12 in the above mentioned wavelength-dependent direction is 60mm, the step 16 is formed at a position of 40mm from a left end of the dielectric substrate 12. However, the position of the step 16 is just one example and may be changed as appropriate within a range of the length of the patch conductor 14, that is, under the patch conductor 14.

Moreover, formed on the whole lower main surface of the dielectric substrate 12 having the above stated step 16 is a ground conductor 18 made of a metal such as copper as with the patch conductor 14.

Furthermore, a connector 20 is provided on the lower main surface of the dielectric 12. An outer conductor 20a of the connector 20 is connected to the ground conductor 18, and an inner conductor 20b thereof is passed through the ground conductor 18 and the dielectric substrate 12 to the upper main surface of the dielectric substrate 12, and connected with the patch conductor 14.

By forming the step 16 on the dielectric substrate 12 as stated above, a spacing between the patch conductor 14 and the ground conductor 18 becomes nonuniform between a range of 22.5mm on the left side of the patch conductor 14 and a range of 2.5mm on the right side of the same in the direction of length. More specifically, a spacing G1 between the patch conductor 14 and the ground conductor 18 is 4mm on the left side, whereas a spacing G2 between the patch conductor 14 and the ground conductor 18 is 1mm on the right side. That is, in this embodiment, the thickness of the dielectric substrate 12 is nonuniform in the direction of the wavelength-dependent length of the patch conductor 14.

When the thickness of the substrate is discontinuous or nonuniform, it can be seen that the radiation efficiency varies depending on the thickness of the substrate according to an experimental result shown in Figure 3. In Figure 3, a solid line shows changes in radiation efficiency (εr) in the air with a dielectric constant of 1, a dotted line shows changes in radiation efficiency in the case of this embodiment using an alumina substrate with a dielectric constant of 9.7, and a dashed line shows changes in radiation efficiency in the case of using a substrate with a dielectric constant of 37. In this manner, by changing the radiation efficiency in the direction of wavelength-dependent length, an

antenna gain becomes asymmetrical as shown in Figure 4, which thus make it possible to achieve asymmetrical directivity as shown in Figure 5. For reference's sake, Figure 6 represents a conventional patch antenna's directivity. However, this directivity of Figure 6 is symmetrical.

In the embodiment shown in Figure 1 and Figure 2, the dielectric substrate thickness (the spacing between the patch conductor and the ground conductor) is kept at 1mm on the right side of the step 16 so that the thickness becomes nonuniform in the direction of wavelength-dependent length. Alternatively, as with an embodiment shown in Figure 7, the substrate thickness may be reduced only at one part in the direction of length. More specifically, in the Figure 7 embodiment, the substrate thickness G2 between the step 16 and a step 17 is made smaller than the substrate thickness G1 at the remaining area. In this embodiment, G1 = 4mm and G2 = 1mm. The result of the experiment has revealed that the radiation characteristic in the direction of length of the patch antenna 10 exhibits left-right asymmetry in the Figure 7 embodiment as well. Therefore, the patch antenna 10 of the Figure 7 embodiment has also asymmetrical directivity.

Moreover, in both of the above mentioned two embodiments, the thickness of the ground conductor 18 is increased at the thinner part of the patch antenna so that the patch antenna has a uniform thickness of 4mm, for example, in its entirety. Alternatively, as shown in Figure 8 and Figure 9, the thickness of the conductor 18 may be uniform regardless of the thickness of the dielectric substrate 12. This would obviously save material for the conductor, but bring about a drop in mechanical strength.

Furthermore, in the above stated embodiments, the thickness of the dielectric substrate 12, that is the spacing between the patch conductor 14 and the ground conductor 18 is nonuniform or discontinuous in order to make the radiation characteristic

nonuniform. Alternatively, as with the Figure 10 embodiment, the dielectric constant may be nonuniform or discontinuous in the direction of length.

More specifically, in the patch antenna 10 shown in Figure 10, the dielectric constant of the dielectric substrate 12 is made discontinuous at a position corresponding to the step in the above mentioned embodiments. For example, a left dielectric substrate 121 is formed of alumina, for example, and its dielectric constant is 9.7, for example, and a right dielectric substrate 122 is formed of high-dielectric ceramic, for example, and its dielectric constant is 37, for example. In this manner, by changing the dielectric constant of the dielectric substrate 12 in the direction of wavelength-dependent length of the patch conductor 14, the radiation characteristic in that direction can be also made nonuniform, and thus it is possible to realize asymmetrical directivity.

Besides, in the above mentioned embodiments, asymmetrical directivity is achieved within an E-plane of the patch antenna. However, the present invention can be also used for realization of asymmetrical directivity within an H-plane.

In the above described embodiments, by forming the dielectric substrate 12 from a material with a high relative dielectric constant, the above stated antenna size can be further reduced. More specifically, a material with a relative dielectric constant of 100 or more may be used for that. Figure 11 and Figure 12 show still another embodiment of the present invention in which the size is reduced by means of such a high relative dielectric constant.

In the embodiment shown in Figure 11 and Figure 12, the dielectric substrate 12 made of a dielectric material with a relative dielectric constant of 100 or more is employed, and the size of the dielectric substrate 12 is 7 x 12mm, for example.

In addition, as a matter of course, the radiation efficiency of the patch antenna 10 is changed in the direction of antenna length (the direction of wavelength-dependent

length of the patch conductor 14) in the embodiment shown in Figure 11 and Figure 12 as well. More specifically, in this embodiment, the step 16 is formed on the dielectric substrate 12.

For further size reduction, the patch antenna 10 of an embodiment shown in Figure 13 and Figure 14 is proposed.

In the embodiment shown in Figure 13 and Figure 14, the dielectric substrate 12 is formed by using a material with a relative dielectric constant of 100 or more and its size is 10 x 5mm, for example. Also, the patch conductor 14 of the same size is formed on the dielectric substrate 12. Loaded on the patch conductor 14 is a dielectric sheet or plate 22 made of the same material as or similar material (with a high relative dielectric constant) to that of the dielectric substrate 12. The size of the loaded dielectric 22 is the same as that of the dielectric substrate 22, 10 x 5mm, for example. The remaining area is the same as that of the patch antenna 10 of the embodiment shown in Figure 11 and Figure 12.

In addition, as a matter of course, the radiation efficiency of the patch antenna 10 is also changed in the direction of antenna length (the direction of wavelength-dependent length of the patch conductor 14) in the embodiment shown in Figure 13 and Figure 14. More specifically, in this embodiment as well, the step 16 is formed on the dielectric substrate 12.

The patch antenna 10 can be built into a cellular telephone if its length is about 10mm as with the embodiment shown in Figure 11 and Figure 12 and the embodiment shown in Figure 13 and Figure 14.

Figure 15 shows a state of the patch antenna 10 of the above mentioned embodiments that is built into a cellular telephone. The cellular telephone 100 includes a housing 102. A display 104 made of an LCD panel, for example, is formed on one side of the housing 102, that is, on the side coming close to or making contact with the head of a

person (not illustrated). A keyboard 106 is arranged on the same side below the display 104. Thus, the user can operate the keyboard 106 to send or receive e-mail while watching the display 104.

Meanwhile, the housing 102 has a built-in substrate 108 on which a required electronic circuit 110 (including a computer chip, a memory device, etc., for example) is mounted. The patch antenna 10 is preferably attached to the substrate 108 and, although not shown, connected to the electronic circuit 110 via a lead. However, since it is well known how to connect an antenna with a cellular telephone, a more detailed description on that is omitted here. The patch antenna 10 is arranged in such a manner that the direction of its length (the direction of wavelength-dependent length of the patch conductor 14) matches the direction of thickness of the housing 102. Thus, the housing 102 of the cellular telephone 100 of this embodiment is at least 10mm or more in thickness. In addition, if the patch antenna 10 is further reduced in size, it is possible to decrease the thickness of the housing 102 of the cellular telephone 100 accordingly.

In making a call or receiving a call on the cellular telephone 100 of this embodiment, as being commonly well known, a person has a conversation with a speaker (not shown) provided in the vicinity of the display 104, on his/her ear. Thus, the patch antenna 10 is coupled with the human body on the side thereof having the display 104, that is, the side thereof making contact with the head of a person.

Accordingly, in an embodiment of Figure 15, the patch antenna 10 is arranged in such a manner that the side of the patch antenna 10 with higher radiation efficiency, that is, the side with a larger radiation pattern is faced opposite to the side making contact with the person's head. By doing this, the antenna characteristic of the cellular telephone 10 can be less affected by the coupling with the human body.

Besides, in the embodiment of Figure 15, the patch antenna 10 is arranged at an

upper part inside the housing 102 of the cellular telephone 100. Nevertheless, the arrangement position of the patch antenna 10 may be an arbitrary one. For example, a lower end inside the housing 102 is easily conceivable for that.

Moreover, in the embodiment of Figure 15, the housing 102 of the cellular telephone 100 is of straight type. Alternatively, it may be a foldable or collapsible housing, rotatable housing, or slidable housing. In this case as well, the antenna may be stored at an arbitrary possible place.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.